v1.0 - 7th December 1998.Ω00 ¡00

BROKEN R PARITY, NEUTRINO ANOMALIES AND COLLIDER TESTS

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The solar and atmospheric neutrino anomalies constitute the only solid and most remarkable evidence for physics beyond the Standard Model, indicating that the lepton mixing matrix is fundamentally distinct from that describing the quarks. Here I will report on how supersymmetry with spontaneously or bilinearly broken R Parity provides a predictive theory for neutrino mass and mixing which leads to a solution of neutrino anomalies which can be clearly tested at high energy accelerators.

1 Motivation

The simplest interpretation of the solar and atmospheric neutrino data [1,2,3] indicate that, in contrast to quark mixing, possibly two of the lepton mixing angles are large. Here I discuss how supersymmetry with broken R Parity provides a predictive theoretical model for neutrino mass and mixing which solves the solar and atmospheric neutrino anomalies in a way that allows the leptonic mixing angles to be probed at high energy accelerators.

R-parity conservation is an `ad hoc` assumption in the MSSM and $\not{R}_p$ may arise `explicitly` as unification remnant or `spontaneously` by $SU(2) \otimes U(1)$ doublet left sneutrino vacuum expectation values (VEVS) $\langle \widetilde{\nu}_i \rangle$ as originally suggested [4,5] but with an `ad hoc` set of explicit breaking terms [6] to comply with LEP data on Z width. Preferably we break R-parity spontaneously through `singlet right sneutrino VEVS`, either by gauging L-number, in which case there is an additional Z [7] or within the $SU(2) \otimes U(1)$ scheme, in which case the `majoron` is an $SU(2) \otimes U(1)$ singlet, with suppressed Z coupling [8]. Spontaneous R-parity violation may lead to a successful electroweak baryogenesis [9].

If R-parity is broken spontaneously then `only bilinear` $\not{R}_p$ `terms arise in the effective theory` below the $\not{R}_p$ violation scale. Bilinear R–parity violation may also be assumed `ab initio` as the fundamental theory. For example, it may be the only violation permitted by higher Abelian flavour symmetries [10]. Moreover the bilinear model provides a theoretically self-consistent scheme in the sense that trilinear $\not{R}_p$ implies, by renormalization group effects, that also bilinear $\not{R}_p$ is present, but `not` conversely. The simplest $\not{R}_p$ model (we call it $\not{R}_p$ MSSM) is characterized by three independent parameters in addition to those specifying the minimal MSSM model. As shown in ref. [11] this leads to a predictive pattern for neutrino masses and mixing angles which provides a solution to the solar and atmospheric neutrino problems. It also predicts a well specified pattern of $\not{R}_p$ phenomena that can be tested at collider experiments, providing an independent determination of neutrino mixing angles at high energy accelerator experiments.

2 Bilinear $\not{R}_p$ MSSM

The minimal supergravity version of R-parity breaking MSSM [12] is specified by the superpotential,

$$W = W_{MSSM} + \epsilon_i L_i \widehat{H}_u \qquad (1)$$

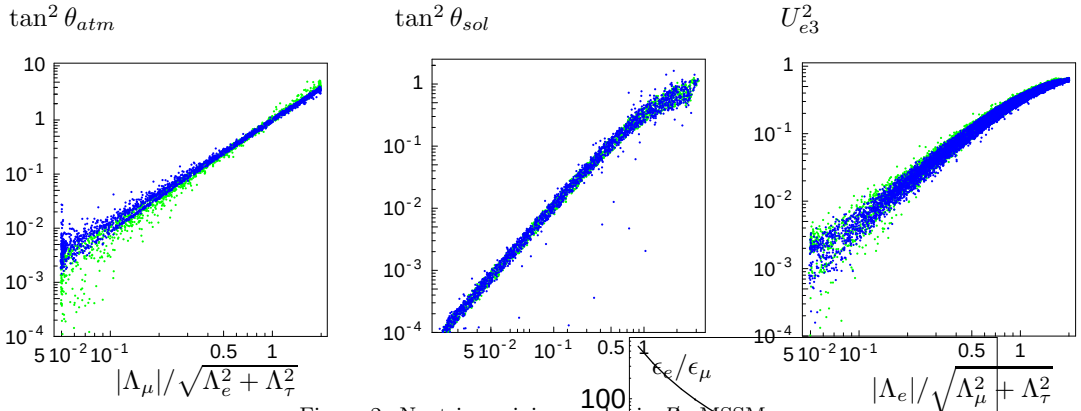

Figure 2. Neutrino mixing angles in $\not{R}_p$ MSSM.

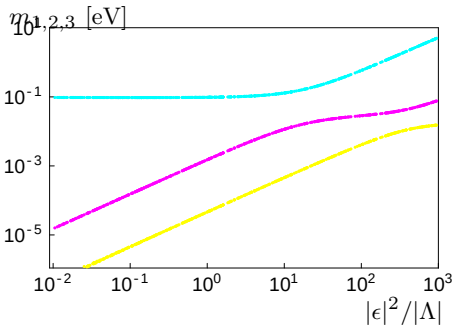

Figure 1. Typical neutrino masses in $\not{R}_p$ MSSM.

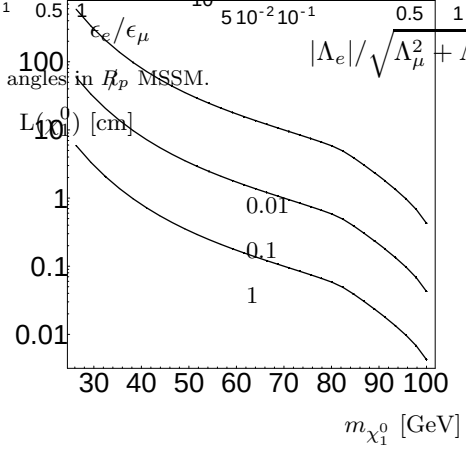

Figure 3. Typical neutralino decay length in $\not{R}_p$ MSSM.

Since lepton number is broken, neutrinos pick up a mass. The expected neutrino mass pattern is illustrated in Fig. (1), taken from [11]. It is typically hierarchical since only one neutrino acquires mass at the tree level, while the others get mass from calculable radiative corrections [11]. As a result neutrino masses can account for the solar and atmospheric neutrino problems *. Having only bilinear R-parity violating terms as the origin of the neutrino masses implies also that the three neutrino mixing angles (assuming CP conservation in the lepton sector) are determined as functions of the three bilinear $\not{R}_p$ terms, leading to a predictive scenario, independently of any particular form for the charged lepton mass matrix. This is illustrated in Fig. (2), taken from [11]. As can be seen, large angle solar solutions, LMA and LOW, now preferred by solar spectrum data and by the global fit of all solar neutrino data, as well as small angle solution (preferred by the rates) can be accounted for within the theory. However, as explained in [11], for the very particular case of strictly universal boundary conditions at the unification scale, consistency with the reactor experiments [14] implies the SMA solar solution.

3 Implications

There are a variety of implications of $\not{R}_p$ models [15]. The most obvious is that, unprotected by any symmetry, the lightest supersymmetric particle (LSP), produced with MSSM-like cross sections, will typically decay inside the detector, as shown in Fig. (3), taken from [16] Such decays are mainly into `visible modes`. Just as the neutrino mixing angles characterizing the neutrino anomalies, in our bilinear $\not{R}_p$ MSSM model also the neutralino de-

*For such small masses neutrinoless double beta decay has been shown to be too small to observe [13]

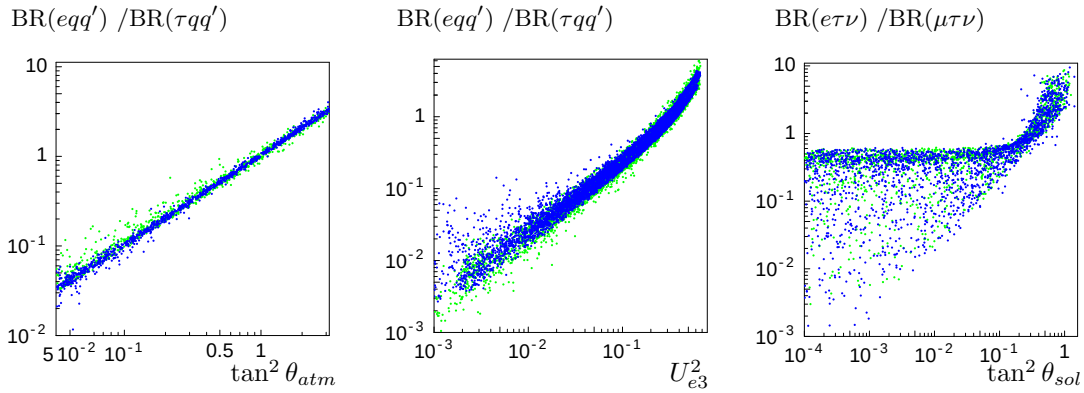

Figure 4. Neutralino BR in bilinear $\not{R}_p$ MSSM.

cay branching ratios are determined by the same three fundamental $\not{R}_p$ parameters in eq. (1). More exactly the neutrino mixing angles are correlated with `ratios` of $\not{R}_p$ parameters. These may be taken as the Λ_μ/Λ_τ for the atmospheric angle, ϵ_e/ϵ_μ for the solar angle, and Λ_e/Λ_τ for the angle which is probed by the reactor experiments [14]. Here $\Lambda_i \equiv \epsilon_i \langle H_d \rangle + \mu \langle \widetilde{\nu}_i \rangle$, μ being the standard Higgsino mixing term. As shown in ref. [11] due to the minimization conditions the Λ ratios do `not` introduce independent parameters, hence the predictivity of the theory is manifest. As Fig. (4) indicates, the LSP decay branching ratios are strongly correlated with the leptonic mixing angles [†].

Neutralino decays can have remarkable consequences for gluino cascade decays at the LHC, enhancing high lepton multiplicity event rates and, correspondingly, thus decreasing the missing momentum signal expected in the R-parity conserving MSSM [18]. If R parity is broken particles other than the neutralino can be the LSP. One example is the stop [19]. In Fig. (5) we illustrate how two-body $\not{R}_p$ decays of the lightest stop can be sizeable when compared with standard decays [20]. R parity violation can also affect gauge and Yukawa unification [21], texture predictions for V_{cb} [22] as well as $b \to s\gamma$ [23]. Turning to accelerators, $\not{R}_p$ can affect the physics of the top quark [24] and it can lead to new signals for chargino production at LEP2 [25], and affect the phenomenology of supersymmetric scalars due to Higgs boson/slepton mixing [26].

[†]The possibility of probing leptonic mixing angles at accelerator experiments in $\not{R}_p$ models has been previously considered in refs. [5,17].

Acknowledgments

This work was supported by DGICYT grant PB98-0693 and by the EEC under the TMR contract ERBFMRX-CT96-0090. M.H. was supported by the Marie-Curie program under grant No ERBFMBICT983000 and W.P. by a fellowship from the Spanish Ministry of Culture under the contract SB97-BU0475382.

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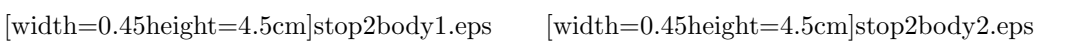

Figure 5. Stop decay BR in bilinear $\not{R}_p$ MSSM.

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